(A+B+C+D) (A+b+C+D) (A+b+C+ d) (A+B+C+ d)
(A+B+c+D) (A+b+c+D)
(a +B+c+D)
(a +B+C+D) (a +B+C+ d)

or, what comes to the same thing,

aBCD+abCD
ABCd+ABCD+AbCD
ABcd+ABcD

I do not think there would be any great difficulty in constructing a machine which should work the logic of relations with a large number of terms. But owing to the great variety of ways in which the same premises can be combined to produce different conclusions in that branch of logic, the machine, in its first state of development, would be no more mechanical than a hand-loom for weaving in many colors with many shuttles. The study of how to pass from such a machine as that to one corresponding to a Jacquard loom, would be likely to do very much for the improvement of logic.

C. S. PEIRCE.

The Functions of the Brain. By DAVID FERRIER, M. D., LL.D., F. R. S. Second Edition. G. P. Putnam's Sons. New York, 1886. Pp. xxiii., 498.

Die Functions-Localization auf der Groshirnrinde. Von L. Luciani und G. Seppilli. Deutsche Ausgabe von Dr. M. O. Fraenkel. Leipzig, 1886. Pp. vii., 414.

When the first edition of Ferrier's work appeared in 1876 it attracted the attention of English readers to the subject of the localization of brain functions, and made an important addition to the mass of facts which had already begun to accumulate upon that subject. Fritzsch and Hitzig had determined in 1870 the existence of a definite area on the surface of the brains of vertebrates, irritation of which produced movements of the limbs, and destruction of which caused paralysis. Ferrier not only confirmed the results of the German physiologists, but went a step farther and succeeded in demonstrating the existence of various sensory areas in the brain, destruction of which produced a loss of some one of the powers of conscious perception. It was very natural that results of such physiological importance should be tested carefully, and there is probably no field of inquiry in which during the past ten years more active work has been done and more acrimonious controversy has arisen. Hardly any two investigators can be found who agree as to the extent of the various sensory areas, and the most different opinions as to the interpretation of the results of experiment have been defended. Ferrier's second edition is issued partly in order to offer new facts from new experiments and to modify former opinions in light of these new facts, partly in order to reply to criticism, and partly in order to defend his own interpretation of his facts. The work is almost wholly rewritten, and differs in so many respects from the first edition that it requires notice.

The work of Luciani and Seppilli received the Fossati prize of the Institute of Science of Lombardy, and was considered worthy of immediate translation into German, not only because of the new discoveries and new views contained in it, but also because of the

singularly unprejudiced and impartial views presented of the entire controversy. And this latter characteristic deserves to be commended, for much that is valuable in the writings of Ferrier, Goltz, Munk, and others, who have taken an active part in the discussion regarding the localization of functions, is obscured by the intensity of personal criticism and recrimination with which it is loaded down. The Italian authors, though holding very definite positions of their own, have succeeded in stating the views of opponents with fairness, and have suggested many probable interpretations of seemingly contradictory facts which may reconcile the inconsistent statements. They have added to the value of their work by appending to it a collection of cases of brain disease in man, which enables them to compare the results of physiological experiment with those of pathological observation.

In spite of the criticism of Goltz it must be admitted that the theory of localization has gained almost universal acceptance. Various areas of cortex of the brain are now admitted to preside over and to be necessary to various forms of mental activity. Certain parts of the cerebral cortex receive impulses from the sensory organs and preserve them as memories. Other parts send out voluntary impulses to the motor apparatus. The motor areas are definitely known and accepted. The controversy now among physiologists is regarding the exact limits of the different sensory areas. Ferrier lays down these areas in his diagrams as little circles, each separate from every other; and this extreme position must be admitted to be a logical consequence of the admission that localization is possible. Munk extends his areas somewhat more widely, does not limit them so exactly, and yet does not allow one area to invade the domain of the next. He goes even further than Ferrier in locating the visual sense, making different parts of the accepted cortex correspond to different parts of the retina. Luciani holds that each sensory area is extensive, and that, at its borders, it not only is not sharply marked off from, but really overlaps that of adjacent areas. Goltz admits that there is a functional difference between the anterior half and the posterior half of the brain, but will not allow that any distinct sensory or motor area can be outlined, claiming that the assertion of Flourens was correct and that the brain acts as a whole.

A distinction has been proposed by Exner which should be mentioned here. Exner believes that it is necessary to admit the existence of both absolute and relative functional areas. An absolute area is one, injury to which is always followed by loss of the function. A relative area is one, injury to which is sometimes but not always followed by a loss of the function. For each sense there is an absolute area, which is surrounded by an extensive relative area, and the relative areas for different senses may to some extent coincide. This distinction is virtually admitted by Luciani, whose experiments prove that loss of function is permanent when the absolute areas are destroyed, but may be temporary when the relative areas only are affected. It is not admitted by Ferrier, yet his own account of his experiments may be cited in favor of such a view, for he admits that in some of his experiments the function returned after the supposed centre was destroyed. (See p. 22 *et seq.*, where it is stated that destruction of the angular gyrus produces only transient loss of vision in the opposite eye, while if the destruction also involves the occipital lobe there is also permanent hemiopia).

It is not admitted by Munk, and yet his distinction in the case of disturbances of sight, between psychical and cortical blindness, might easily be referred to such a simple explanation. To an independent inquirer there seems to be much in favor of the position of Luciana and Exner, as it appears to reconcile in some degree the conflicting statements.

Any one who reads these statements carefully, and who also reads the detailed account of the experiments upon which they are based, must be impressed at once with the fact that the differences are due rather more to the interpretation of the experiments than to their actual results. It is a very difficult matter to ascertain just what functions are wanting, or to what degree any one function is impaired in an animal after an operation on the brain. The result which the observer looks for is the one most likely to be found, and as an animal cannot communicate its own sensations in language, much is left to be guessed at. It is for this reason that experimentation in animals seems to be of much less importance in deciding upon the location of sensory areas than the results of pathological observation in man. Munk, Exner, and Luciani appeal to pathology frequently and claim that it supports their various positions. Ferrier seems less inclined to admit this kind of evidence (p. 270), possibly because it fails to support some of the positions which he holds as opposed to other observers—*e. g.*, as to the location of the tactile centres and the visual centre. Yet it might be supposed that the English physiologist would insist upon this class of evidence, for he has directed a number of operations upon the human brain in cases of paralysis recently performed in London by Victor Horseley. Such cerebral operations are the practical outcome of the doctrine of localization, and have been its most brilliant confirmation. For the situation of the motor areas of the brain being agreed upon by all experimenters, it has been possible in cases of paralysis from brain tumor or abscess to trephine the skull and remove the disease from the brain, with the result of saving the life, and in some cases of restoring partially or wholly the function of the paralyzed limb. There is therefore a practical importance in determining the location of the sensory areas of the brain, in order that such operations may be performed when some one sense is lost as well as when some one limb is powerless. The importance of observations as to the effect of disease on the human brain, and the necessity of accurate localization of such disease after death, has not been exaggerated, and considerable effort is being made on all sides to collect and compare cases of such a kind. A definite settlement of the controversy does not seem to be far distant, for in respect to the function of sight authorities are now well agreed, the visual area of the human brain being undoubtedly in the occipital region.[1] We may hope for equally positive results regarding other areas.

The work of physiologists upon the cortex has brought to light the importance of distinguishing reflex and automatic activity from conscious volitional motion; and the subcortical perception of sensations, which always results in an automatic response, from the cortical perception of sensations, which is always conscious, and which may or may not give rise to action. And among the most interesting results is the determination of the facts that conscious mental-action perception, together with memory and volition, are

[1] E. C. Seguin, Jour. of Nerv. and Ment. Dis., Jan., 1886.

functions of the cortex alone; also, that the association of ideas is secured by the intimate union of various areas of the cortex, through the medium of nerve fibres passing just beneath the surface.

In view of the remarkable work which is being done at present in the department of psycho-physics in measuring the time of such processes of association, the study of the physical basis of the physiological process gains in interest.

The physiologists have succeeded in demonstrating the complex organic basis of memory by these experiments upon the cortex. It is now evident that we must speak rather of memories than of memory—each sensory or motor act leaving behind it a molecular change in the cortex which is to be regarded as the physical substratum necessary to recollection or reproduction. And as the memory of any single object is made up of a number of revived impressions, each derived through a separate sense, and each received in a different area, the mental image of the object involves the activity of various parts of the cortex, the revival of numerous, distinct memory-pictures, joined in a complex unit. It follows that a single set of memories may be lost by disease in one part of the brain, while other memories remain, a conclusion which is amply illustrated in the phenomena of aphasia. (Ferrier, pp. 440–460).

That there is any necessity for postulating "ideational centres" distinct from the correlated sensory and motor centres, is combatted by Ferrier. "We have in the sensory and motor centres of the cortex the substrata of the respective forms of sensory perception and ideation, and of the individual acts of volition, simple and compound, as well as of the feelings associated with their activity. It seems more reasonable to suppose that there may be higher and lower degrees of complexity or evolution in the same centres than to assume the separate existence of more highly evolved centres for which no evidence is obtained by the results of experimental research." (Page 460.) "Intelligence and will have no local habitation distinct from the sensory and motor substrata of the cortex generally. There are centres for special forms of sensation and ideation, and centres for special motor activities and requisitions, in response to and as association with the activity of sensory centres; and these, in their respective cohesions, actions and interactions, form the substrata of mental operations in all their aspects and all their range." (Page 467.)

The discussion of the psychological side of brain action is more intelligent and philosophical in the English than in the Italian work. But both of these books may be recommended for careful perusal to anyone who desires to become familiar with the facts upon which the theory of the localization of brain functions is based.

M. Allen Starr.

Francis Galton on the Persistency of Type.

In his opening address as President of the Anthropological section of the British Association, at its Aberdeen meeting, Francis Galton gave an account of his researchesregarding the inheritance of size in seed and of stature in man, as well as certain generalizations which he deduces from his observations. His observations